National Aeronautics and Space Administration

Briefing to Explore NEOs Objectives Workshop (Explore NOW):

Exploration Precursor Robotic Missions (xPRM) Point of Departure Plans

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Background and Context

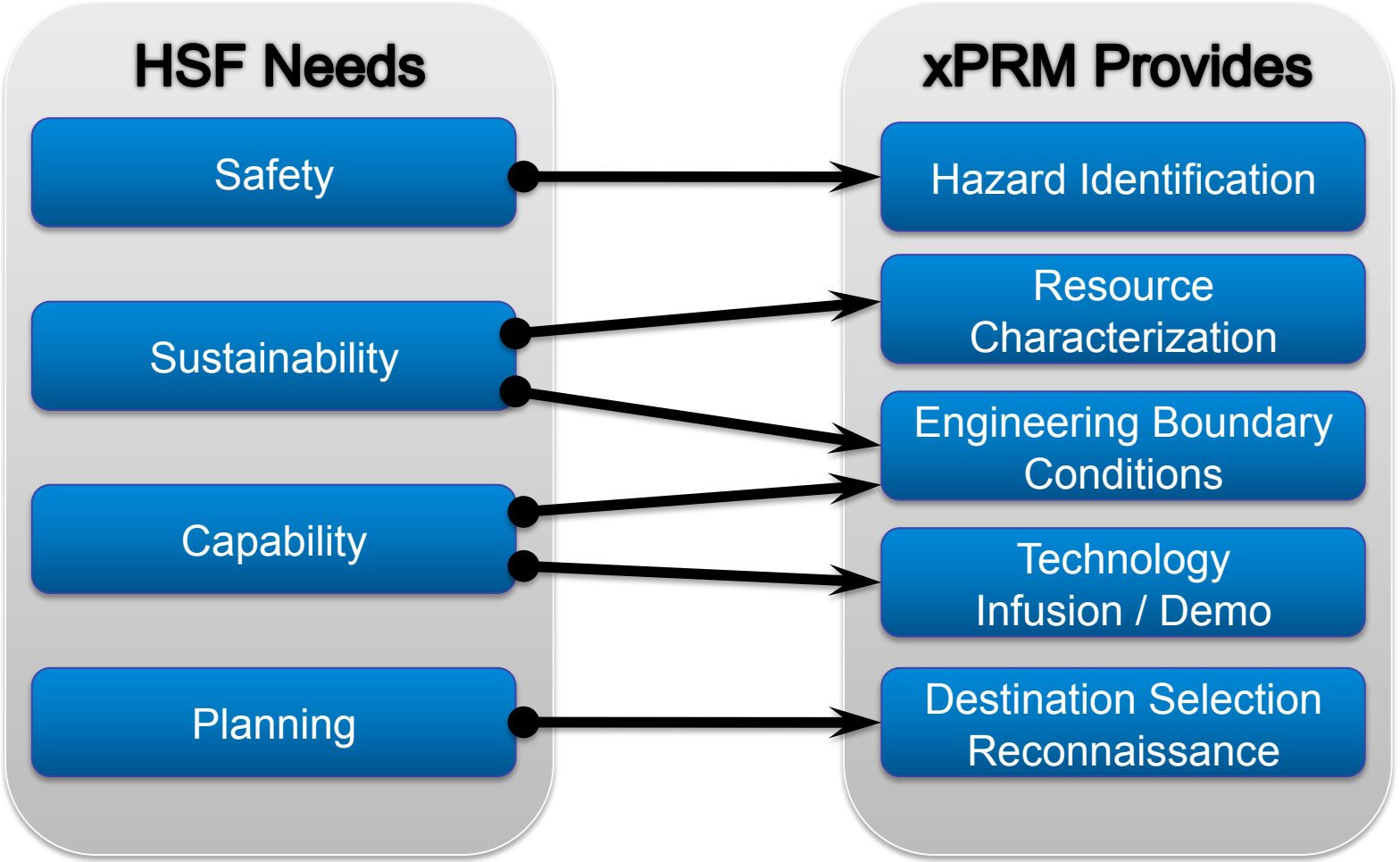
- **Human Exploration precursors were essential to the success of Project Apollo in the late 1960's to early 1970s:**
  - *Robotic precursors such as Surveyors and Lunar Orbiters defined the engineering boundary conditions and environments for human exploration of the Moon, as well as potential hazards*
- **More recently, human exploration precursors have been designed and flown in support of the 2004 National Space Policy Directive 12 Plan:**
  - *The Lunar Reconnaissance Orbiter (LRO) and Lunar CRater Observation and Sensing Satellite (LCROSS) are recent/current human exploration robotic precursors designed to provide applied knowledge essential for the safe and cost-effective return of humans to the lunar surface*
- **No matter the human spaceflight destination beyond low Earth orbit (LEO), exploration robotic precursors are essential to ensure human health and safety:**
  - Comments to this effect were made by the Augustine Committee in 2009
  - Exploration Precursor Robotic Missions to future human destinations are particularly important in the decade from 2010 to 2020 to characterize:
    - *Near Earth Objects (NEOs)*
    - *Lunar resources (esp. volatiles)*
    - *Mars orbit and surface (resources, hazards, dust, toxicity)*

Introduction

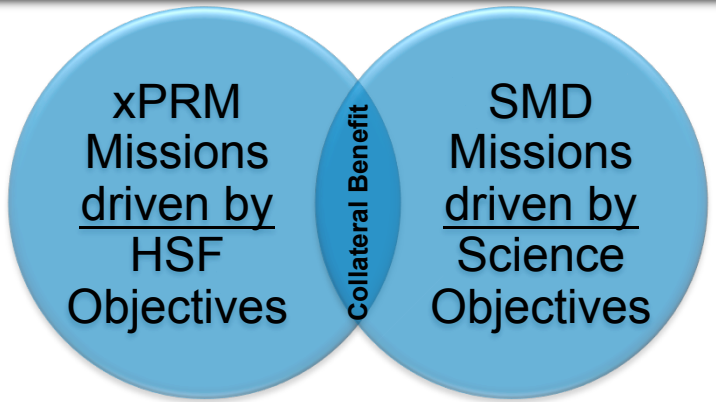
- NASA Planning for the FY2011 budget request calls for *a **"steady stream of [Exploration] Robotic Precursor missions"*** and related activities:
  - We define this effort as xPRM
  - The xPRM effort would consist of **two Programs:**
    - **xPRP:** set of linked flight missions, instrument developments, and R&A for the purpose of acquiring applied precursor knowledge for human spaceflight (HSF)
      - Cost range $500M to $800M (total mission life cycle cost with launch)
    - **xScout:** focused, less-expensive, higher-risk missions, with cost cap of $100M to $200M including launch
  - These proposed program lines include a portfolio of missions traceable to HSF precursor requirements

Why xPRM? *Enabling HSF proactively…*

- xPRM uniquely and specifically addresses HSF priority needs.



xPRM uniquely compliments SMD missions



- Science Mission Directorate (SMD) missions are driven almost entirely by science objectives set by the National Academies Decadal Survey process, and therefore do not typically address high-priority Exploration precursor/HSF objectives
- xPRM missions will be designed to conduct the precursor measurements/experiments to quantitatively inform and support HSF objectives
  - These are different objectives that lead to different activities in many cases
- There are exceptions in both directions
  - Where synergy exists, we will work to take smart advantage of it

Sample Topic: Oxygen content of lunar regolith	
HSF/xPRM Questions:	**SMD/Science Questions:**
Where is it localized and at what form and concentration? Can it be accessed? How to best access and process it into a HSF "resource"?	How does spatial distribution of oxygen inform the investigations of volatile sources and sinks within the solar system? [includes oxygen-bearing molecules]

xPRM Top Level Objectives and Principles

- To conduct **precursor measurements/experiments*** in support of human exploration:
  - Quantify the engineering boundary conditions associated with the environments of human exploration beyond LEO.
  - Indentify hazards (to ensure safety)
  - Identify resources (to facilitate sustainability, lower launch mass, and “living off the land”)
  - Provide strategic knowledge to inform the selection of human exploration destinations
- To provide a platform for **technology flight demonstrations** which support human exploration.

- To **coordinate** with other NASA directorates.
  - Avoid overlap, identify complementary objectives, leverage dual-use opportunities
- To **foster competition** in mission/payload/investigation selections.
- To foster opportunities for **international collaboration** which benefit human exploration.
- To foster **participatory exploration** opportunities

*An HSF priority **precursor measurement/experiment** is a necessary component of any xPRM mission.

Exploration Precursor Robotic Program (xPRP) Planned Content

- Flight Missions:
  - Precursor measurements/experiments to enable safe and effective HSF beyond LEO
  - Platforms for technology demonstration
- Instrument Development (Missions of Opportunity)
  - Enhance investigation opportunities and promote partnerships with Internationals, other Agencies, or SMD
  - Instruments will generally be competed with approximately annual SALMON-like call or perhaps in partnership with SALMON (SMD's Stand Alone Missions of Opportunity)
  - Fly on non-xPRP missions
- Research and Analysis for Exploration
  - Turn data into Strategic Knowledge for Exploration
    - Engineering information, visualization, dissemination
    - Institutes, workshops, research investigations

xScout Program
Planned Content

- Principal Investigator (PI)-led or small, center-led approach to reduce costs
- Budgeting $100-$200M per mission
  - Includes approx. $50M for access to space (e.g.: Dual-Payload Attachment Fitting, co-manifest or small Expendable Launch Vehicle)
- Co-manifest with xPRP missions where practical
- First launch 2014
  - Stretch-goal of 2013 launch readiness (requires dedicated launch)
- 18-24 month cadence
- Higher-risk tolerance

- **Mission content**:
  - Focused scope in support of HSF objectives:
    - Could **be threshold measurements** or existence-proof experiments
  - xScout AOs written to **complement xPRP portfolio** with the goal of accomplishing **common xPRM objectives**

Point of Departure xPRM Portfolio

- xPRM would be uniquely poised to provide critical strategic knowledge for exploration from a diverse set of destinations.
  - **xPRM starting in this decade would enable Human Exploration in the next.**
    - Analogous to robotic surveyor landers ahead of Apollo human missions
  - Proposed scope **uniquely focuses on HSF objectives** while leveraging unique capabilities of partners.
    - No other program would fulfill this objective.
  - Fully consistent with current best estimate objectives for future HSF at NASA

CY →	2014	2015	2016	2017	2018
xPRP	NEO 	Lunar Lander 		NEO 	Mars 
MOOs	MOO1	MOO2	MOO3	MOO4	MOO5
xScouts	xS1 - NEO	xS2		xS3	xS4

NOTIONAL Point of Departure – Subject to Change

NEO Campaign (Notionally 2014 and 2017)

- $640-840M life-cycle cost mission allocations
- 2025 HSF Asteroid mission would **likely only afford two xPRP opportunities** to inform the HSF architecture, while maintaining other xPRP objectives.
- Need to coordinate with HSF objectives definition teams to determine the appropriate campaign approach, and which combination/sequence of candidate missions:
  - "Shotgun" of 3 or 4 very small spacecraft to rendezvous with separate destinations with a limited focused-measurement payload on single launch
    - Would likely focus on top-level hazards and destination selection criteria
  - "Stack" of 2 "small-Discovery"-Class spacecraft to rendezvous with separate destinations with moderate payload on single launch.
    - Would likely focus on hazards, selection criteria, and more rigorous characterization.
  - Single Discovery-class spacecraft with HSF Objectives
    - More in-depth measurements and investigations at expense of target diversity.
  - NEO Telescopic Survey
    - Helio-centric orbit inside the orbit of earth.
    - Would likely focus on identification and remote characterization (size, spin, albedo, thermal inertia, roughness, trajectory determination, etc) to provide robust slate options for HSF exploration.
- All options have potentially strong collateral value to science and planetary defense.
- As mission definition matures, possible international partnerships will continue to be explored.

NEO Telescopic Survey (NTS) Mission Option

- Current slate of HSF NEO candidates may not be sufficiently robust.

- Per NASA Johnson Space Center analysis: 44-known NEOs are reachable humans assuming notional Ares V-class launch vehicle performance; However:
  - All but 17 may be deemed “too small” to visit by humans
  - Of those, 15 have opportunities in the (very) wide timeframe of interest
  - Of those, only 3 have mission durations on the order of 180 days
  - Of those, only 1 has a launch window in 2025 (the next being 2036 & 2046)
  - There are additional risk factors which could further eliminate candidates (spin rate, binary system, dormant comets)

- NTS could discover 1000’s of additional objects >100m providing a more robust set of candidate targets.

- **Need to determine if this current slate of candidates is “sufficient” and if size and mission duration limits are valid assumptions.**

NEO Rendezvous Mission Objectives

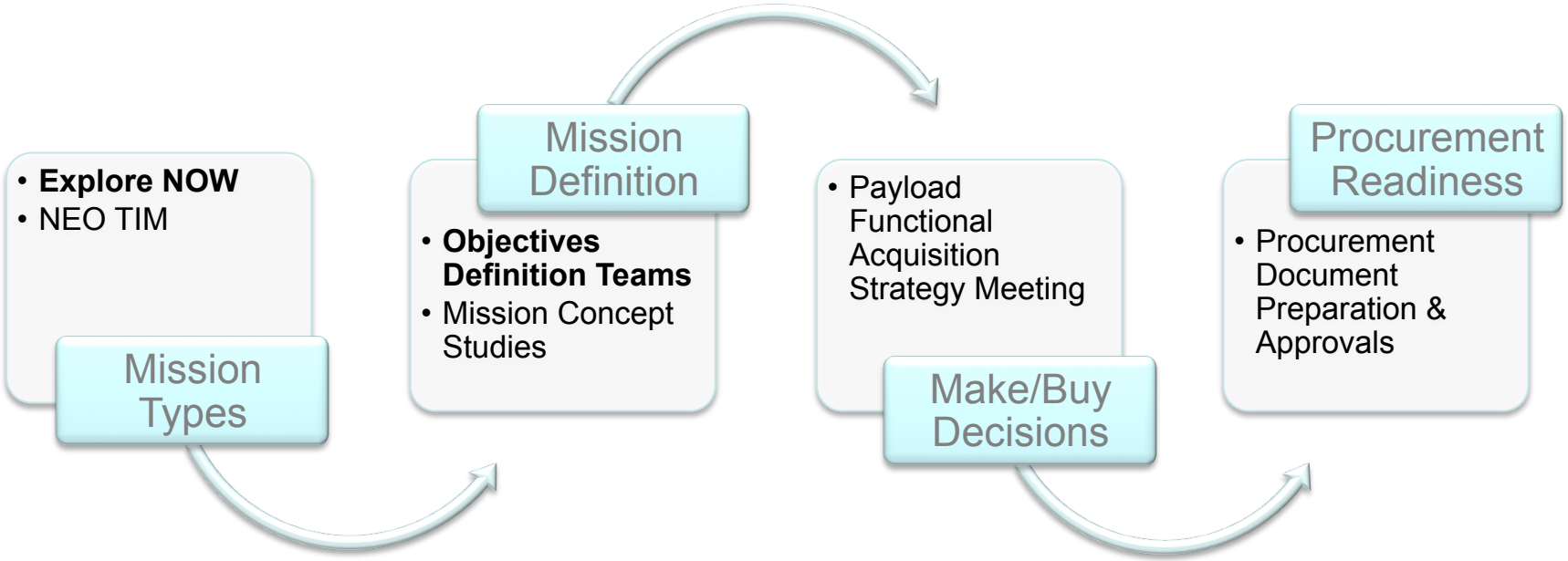
- Rendezvous missions would need to influence engineering concepts for HSF NEO missions in 2025
- Paucity of HSF objectives for NEOs; assumed xPRM Objectives would focus on:
  - Hazards, Prox-Ops, Quantify engineering boundary conditions

- Measurements (potential candidates):
  - Sub-meter-per-pixel imaging in multiple colors (possibly <10cm/pixel)
  - Geodetic imaging lidar altimetry (meter-scale topography)
  - Compositional mapping: Gamma-ray/Neutron Spectrometry (GRNS) best if low altitude orbit can be established for months
  - Small sounding-imaging-radar or long-wavelength sounder for internal structure
  - 2-way RF ranging for gravity field

- Additional Options:
  - Proximity remote sensing, beacon placement, small hoppers, touch & go, grappling, sample return

- Net investigations would be a balance of measurement scope versus target diversity within funding limits.

xPRM NEO Near-term Planning Activities



- **Near-term planning activities will continue to refine objectives, mission types and concepts**
- **Public input solicited at Explore NOW and in upcoming Objective Definition Teams.**

Summary

- xPRM would be uniquely poised to provide critical applied knowledge for Exploration from a diverse set of destinations.
  - xPR Missions starting in this decade would enable Human Exploration in the next
    - Analogous to robotic surveyor landers ahead of Apollo human missions
  - Uniquely focuses on HSF objectives while leveraging unique capabilities of partners.
    - No other program fulfills this objective
  - Fully consistent with direction and best estimate objectives for future HSF at NASA
- Study content is responding to recent change toward NEO focus
- Objective Definition Team Activities and System Engineering Analyses are necessary to refine definitions of mission scope and specific content
- Human Exploration Framework Team products to be folded in as available.

Explore NOW Ties into xPRM Planning

- *Explore NOW* will assist with the planning the scope of potential precursor missions to support the development of knowledge needed to design a human mission to a NEO.
  - To be **most useful** for xPRM planning, identification of knowledge gaps and the measurements to fill them must be tied to Human Spaceflight objectives and activities.

Derived Needs

- Human objectives at NEOs
  - Objectives
  - Activities
  - Target Characteristics

Planning Input

- Knowledge Gaps (that tie to preparation of Human Missions)
- Precursor Measurement Investigations (that tie to Knowledge Gaps)
- Category of Measurement (EBC, Resource, Hazards, Selection, Other)
- Criticality of Measurement

Bonus Question

Given a Human NEO mission of your choice, what TWO robotic precursors would you launch to prepare?